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Relationship of Hydrological Conditions and Populations of Breeding Piping Plovers

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ABSTRACT -- I used hydrological data and surveys of breeding piping plover (*Charadrius melodus*) from 1988 to 1997 to assess the relationship of water levels to piping plover breeding distribution, abundance, and habitat use in North Dakota. Piping plover abundance at wetlands surveyed in all years ($n = 48$) increased significantly as wetness increased ($r = 0.93$, $P < 0.001$). However, individual wetland sites often differed in their response to hydrological conditions with some sites showing significant decreases in piping plover abundance during wet periods. The abundance of piping plovers using the Missouri River system (Oahe and Sakakawea reservoirs and the free-flowing reaches of the river) correlated strongly with upland populations of piping plovers during periods of below-average water levels in the riverine system; however, once water levels within the Missouri River system reach a certain point the relationship turned negative with river populations of piping plovers decreasing and upland populations of piping plovers increasing.

Key words: breeding habitat, *Charadrius melodus*, drought, Missouri River, piping plover, wetlands.

The Northern Great Plains population of the piping plover (*Charadrius melodus*) was listed as a threatened species in 1985 (U.S. Fish and Wildlife Service 1985). The recovery plan for the Great Plains population states that monitoring breeding season abundance and evaluating breeding habitat is a necessary task to meet recovery objectives (U.S. Fish and Wildlife Service 1988). Breeding piping plovers typically use barren or sparsely vegetated areas in close proximity to water. These sites usually are associated with alkaline wetlands (Prindiville Gaines and Ryan 1988), Missouri River sandbars (Dirks et al. 1993), and beaches on Sakakawea (North 1986) and Oahe

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reservoirs. The amount of barren and sparsely vegetated habitat is often influenced by water levels.

Counts of breeding piping plovers were conducted at selected sites from 1983 to 1987. Counts from 1988 to 1997 were conducted with the intent of including all sites with the potential for piping plovers (however, not all sites were counted in all years). My objective is to use the 1988 to 1997 North Dakota piping plover counts, and when appropriate, the 1983 to 1987 data, to describe piping plover distribution, abundance, and habitat use as it relates to hydrological conditions.

METHODS

Surveys for breeding piping plovers were conducted annually from 1988 to 1997 by federal, state, and non-governmental organizations. Sites surveyed were selected based on historical records of piping plover occupancy or the potential for occupancy in the judgement of the surveyors. An attempt was made to survey all selected sites in all years; however, some sites were missed in some years. Surveys also were conducted from 1983 to 1987; however, only a small percentage of sites were surveyed each year.

Surveys were conducted by using guidelines in the piping plover recovery plan (U.S. Fish and Wildlife Service 1988). Counts at wetland and deepwater sites were conducted by walking parallel to suitable shoreline. Counts at riverine sandbars and reservoir islands were conducted by walking suitable habitat or, less frequently, by observations from boats. Counts were conducted between mid-May and mid-June, the peak of piping plover breeding in North Dakota (Prindiville Gaines and Ryan 1988). In addition to the systematic counts, incidental observations of piping plovers at non-traditional sites (e.g., mining spoil sites and newly built islands) also were recorded.

I categorized all sites used by piping plovers into the three broad habitat categories: riverine (i.e., Missouri River system), artificial, and wetland. Riverine sites were further divided into the free-flowing Missouri River (river mile 1299.6 to 1389.0), Yellowstone River, Sakakawea Reservoir, and Oahe Reservoir (North Dakota portion only). Artificial sites were divided into subcategories of impoundments, anthropogenic islands (excluding islands used by piping plovers within impoundments), restored wetlands, roads, and mine spoil sites (e.g., excavated material associated with surface mines). Wetland sites were defined as natural wetlands that could support breeding piping plovers without anthropogenic manipulation.

I recorded habitat attributes for wetland sites from National Wetlands Inventory (NWI: Cowardin et al. 1979) maps and digitized data. The variable wetland type was the deepwater zone for the wetland (i.e., the zone system, class, and water regime modifier). The variables wetland area, wetland perimeter, percentage of wetland in unconsolidated shore zones (perimeter or area, whichever was greater), and percentage of wetland in emergent vegetation zones were determined from digitized NWI data when available, or from NWI maps. I used perimeter and area to calculate an index of shape (i.e., the degree to which the perimeter/area ratio differed from a circle). Index of shape, wetland perimeter, and perimeter/area ratio were all correlated with wetland area at $r \geq 0.60$ (d.f. = 100). Thus, I retained only shape because it is not a square root product of area (as is the perimeter/ratio area) and because it seemed useful as a measure of physical and ecological processes that might influence wetlands (e.g., wind fetch).

I calculated the hydrological condition (i.e., wetness) for each breeding season by using the Palmer Hydrological Drought Index (PHDI) from North Dakota Divisions 1, 2, 4, 5, 8, and 9 (divisions that were generally overlapping with the breeding range of piping plovers in the state) for the months of May and June (National Climatic Data Center 1998). I used the mean of the maximum daily outflow from Garrison Dam for the months of May and June as a measure of river elevations (U.S. Army Corps of Engineers 1998). I used the mean of the maximum daily midnight elevation for the months of May and June for reservoir elevations.

None of the NWI wetland habitat variables were distributed normally, nor was piping plover abundance among wetland sites. Thus, prior to linear and multiple regressions I transformed these data by using log (data) or log (data + 1) and I tested for differences with the Mann-Whitney U-test or Fisher's exact test. Dispersion about the mean is presented as ± SD.

RESULTS

From 1988 to 1997 piping plovers were observed at 130 sites (Fig. 1). Four were categorized as part of the Missouri River system (Missouri and Yellowstone rivers and Sakakawea and Oahe reservoirs), 25 were categorized as artificial, and 101 were categorized as natural wetlands. The sites were distributed among 26 North Dakota counties. However, observed piping plover use in six counties was limited to the Missouri River mainstem (i.e., the county line). Thirty-eight of the 101 wetlands were within 1.6 km of another wetland with observed piping plover use, and the three most heavily used wetlands (64.4, 58.1, and 43.7 birds/year) were all within 3 km of each other.

The Missouri River system supported a mean of 214.2 birds annually over 1988 to 1997 with great interyear variability (range 20-328; Table 1). The mean number of piping plovers occurring annually on artificial sites was 37.3 ± 21.5 (Table 1). Of the 25 artificial sites, nine were impoundments, eight were anthropogenic islands, five were wetland restorations, two were roads, and one was a mining spoil site. Islands were the most frequently used artificial habitat (18.7 ± 21.6 birds/year) followed by impoundments (15.5 ± 17.0 birds/year). Impoundments ranged in size from 49 to 7200 ha. Breeding habitat in impoundments was typically available during drawdowns in the form of exposed beaches and islands.

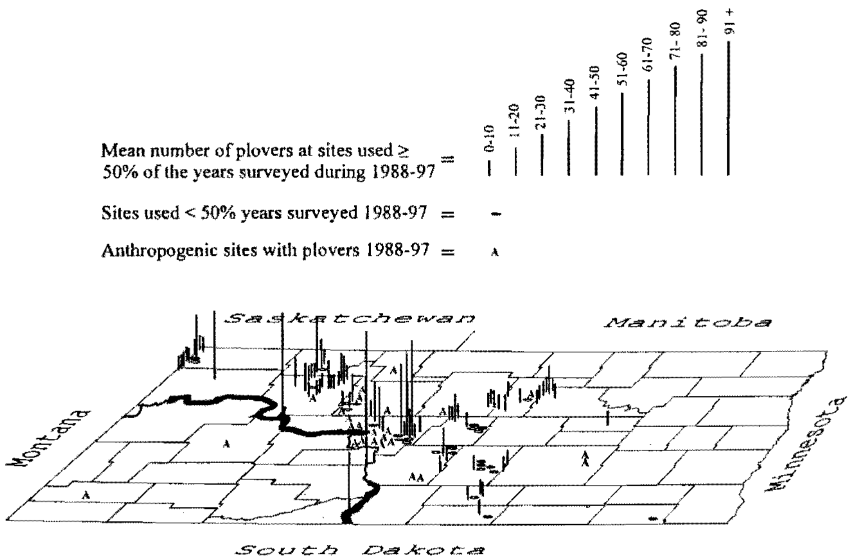

Figure 1. Distribution and use of piping plover breeding sites in North Dakota, 1988 to 1997. Missouri River and Sakakawea and Oahe reservoirs are presented as a single point although observations were distributed throughout the sites.

A total of 101 natural wetlands had at least one occurrence of piping plovers during 1988 to 1997. Three additional natural wetlands and one anthropogenically manipulated wetland were recorded with piping plovers from 1983 to 1987. Wetlands used by piping plovers in North Dakota ranged in size from 3 to 2,576 ha. Of the 101 wetland sites known to have plovers over 1988 to 1997, 61.4% were classified by the NWI as lacustrine/aquatic bed/intermittently-exposed (L2ABG) in the deepwater zone. When weighted by the average number of piping plovers per count at a site, 71.6% of the use occurred on L2ABG wetlands. The mean number of piping plovers per count at a site was significantly correlated with wetland area ($r = 0.38$, d.f. = 100, $P < 0.001$) and the percentage of unconsolidated shoreline ($r = 0.21$, d.f. = 100, $P < 0.05$). Stepwise multiple regression identified the best model for predicting plover abundance at a wetland as:

$$\log(y) = -2.11 + 0.46 * \log(W) + 0.99 * AB + 0.24 * \log(N)$$

where y = number of piping plovers; W = wetland area; AB = 1 if the NWI class of the deepwater zone is aquatic bed, otherwise AB = 0; and N = number of piping plovers within 1.6 km of the wetland ($r = 0.22$, d.f. = 100, $P < 0.001$). The retained variables were all significant at $P < 0.05$.

Table 1. Breeding piping plovers recorded in North Dakota 1988 to 1997 by habitat type.

Year	Palmer Hydrological Drought Index category[a]	State Piping Plover Total	Missouri River System						Artificial sites n = 25	Natural wetlands n = 101
			Missouri River		Oahe Reservoir		Sakakawea Reservoir			
			Plovers	1,000 cfs[a]	Plovers	msl[a]	Plovers	msl[a]		
1988	extreme drought	780[b]	94	(19.8)	31	(1605)	143	(1832)	8	498
1989	severe drought	625[c]	52	(22.7)	63	(1592)	57	(1826)	18	431
1990	severe drought	811	54	(20.5)	59	(1589)	132	(1821)	34	532
1991	moderate drought	1002	83	(20.9)	62	(1591)	164	(1822)	62	631
1992	moderate drought	939	77	(20.0)	91	(1591)	108	(1823)	21	642
1993	normal	1014	125	(17.0)	45	(1601)	5	(1826)	17	822
1994	severe wetness	1169	118	(25.5)	48	(1611)	47	(1845)	42	914
1995	extreme wetness	1172	287	(14.9)	18	(1618)	23	(1843)	40	804
1996	severe wetness	967	45	(37.2)	14	(1618)	67	(1846)	66	775
1997	moderate wetness	921	2	(45.7)	14	(1618)	4	(1851)	65	836
Mean	normal	940.0	93.7	(24.42)	44.5	(1603.4)	75.0	(1833.5)	37.3	688.5
SD		169.4	77.0	(9.63)	25.3	(12.2)	58.4	(11.5)	21.5	164.6

[a] For May/June
[b] Includes six piping plovers on Yellowstone River not included in other columns.
[c] Includes four piping plovers on Yellowstone River not included in other columns.

The number of piping plovers that used the subset of 52 sites (48 wetland and 4 riverine sites) surveyed in all years and the subset of 48 wetland sites surveyed in all years increased over time ($r = 0.67$, d.f. = 9, $P < 0.05$, and $r = 0.91$, d.f. = 9, $P < 0.001$, respectively). However, stepwise multiple regression of the 52 sites against year and PHDI found that PHDI (i.e., wetness) was more significant ($P < 0.001$) to the model than was year ($P > 0.05$: model $r^2 = 69.8$, d.f. = 9, $P < 0.05$). Likewise, for the 48 wetland sites surveyed all years the wetness variable was more significant ($P < 0.10$) than year ($P > 0.10$: model $r^2 = 89.6$, d.f. = 9, $P < 0.001$). From 1988 to 1997 the subset of 52 sites surveyed in all years increased significantly with increasing wetness ($r = 0.82$, d.f. = 51, $P < 0.01$) as did the subset of 48 wetland sites surveyed in all years ($r = 0.93$, d.f. = 47, $P < 0.001$). The 52 sites supported 82.1% of all piping plovers counted in North Dakota from 1988 to 1997 while the 48 wetland sites supported 74.6% of all piping plovers counted at natural wetlands. Further evidence that piping plover populations were affected more by hydrological conditions than by year is that the 12 wetland sites surveyed in all years 1983 to 1997 (a wet-dry-wet cycle based on the PHDI: see Table 1) were significantly correlated with wetness ($r = 0.74$, d.f. = 14, $P < 0.01$) and not year ($r = 0.12$, d.f. = 14, $P = 0.67$).

There was no discernible correlation between hydrological conditions and the percentage of piping plovers using permanent and intermittent wetlands ($r = 0.01$, d.f. = 9, $P = 0.99$). Ninety-eight wetlands had at least three counts from 1988 to 1997. Of those, 18 were positively correlated with the PHDI (i.e., increasing wetness) at $P < 0.10$ whereas 12 were negatively correlated. Wetlands with increased piping plover use during wet periods had a significantly higher percentage of unconsolidated shore than did sites with increased piping plover use during dry periods, but did not differ statistically in other habitat variables (Table 2).

The occupancy rate of the surveyed wetland sites was 0.63 ($n = 829$). When weighted to correct for the 181 missing records, which were biased towards sites that had lower long-term means and towards early years, the occupancy rate was 0.61. For the group of wetlands that averaged less than or equal to five piping plovers over 1988 to 1997 the weighted occupancy rate was 0.47 ($n = 467$). Over the dry period (1988 to 1992) the rate was 0.45 ($n = 206$) and over the wet period (1993 to 1997) it was 0.48 ($n = 213$). The annual occupancy rate of all wetland sites surveyed was not significantly correlated with wetness ($r = -0.10$, d.f. = 9, $P = 0.78$). However, the number of piping plovers per occupied wetland increased significantly with increasing wetness ($r = 0.77$, d.f. = 9, $P < 0.01$).

Water was added to Lake Williams in McLean County during the drought years 1990 to 1992 for the benefit of breeding plovers (Dryer et al. 1993). In spite of the supplemental water the wetland supported only 52% of the number of piping plovers it averaged in the other years. At the same time, nine other wetlands in the complex supported 82% of the number of piping plovers counted annually during the other years.

Table 2. Differences in habitat variables between sites where piping plover abundance was correlated positively with hydrology (wet period sites: $P < 0.10$) and sites where piping plover abundance was correlated negatively with hydrology (dry period sites: $P < 0.10$).[a]

	Wet period sites n = 18	Dry period sites n = 12	U	P
Median wetland area (ha)	151.0	175.5	79.5	0.236
Median shape index	1.72	1.48	122.0	0.568
Median % unconsolidated shore	13.0	0.0	168.5	0.007
Median % emergent vegetation	2.5	9.0	73.0	0.141
Number of sites with h or g NWI modifier[b]	10	8		0.709
Mean number of neighboring birds	22.5 ± 38.9	5.9 ± 18.5	123.0	0.497
Mean number of birds per site per year	15.5 ± 18.6	3.6 ± 2.7	163.5	0.020

[a] All statistical tests used the two-tailed Mann-Whitney U-test except for "Number of sites with h or g NWI modifier" which used Fisher's exact test.

[b] h = permanently flooded, g = intermittently exposed (see Cowardin et al. 1979).

Piping plover abundance on the free-flowing Missouri River was correlated negatively with water releases from Garrison Dam ($r = -0.64$, d.f. = 9, $P < 0.05$) and abundance on Sakakawea and Oahe reservoirs was correlated negatively with water elevations ($r = -0.61$, d.f. = 9, $P = 0.06$ and $r = -0.89$, d.f. = 9, $P < 0.001$, respectively). I ran a correlation on the upland population from sites with complete survey histories from 1988 to 1997 (artificial sites and 48 wetlands surveyed in all years) against the Missouri River population in an effort to evaluate the hypothesis that there are within-year movements between the habitats; the correlations were not statistically significant ($r = -0.43$, d.f. = 9, $P = 0.22$). Of the individual units of the Missouri River system, none were correlated significantly with the number of piping plovers at upland sites. However, during the 1988 to 1992 dry period the correlation between upland populations of piping plover and Missouri River system populations of piping plover was strongly positive ($r = 0.95$, d.f. = 4, $P < 0.05$), whereas from 1992 to 1997, a generally wet period, the correlation was negative, but not statistically significant ($r = -0.31$, d.f. = 4, $P = 0.61$).

DISCUSSION

Recent interyear changes in piper plover abundance in North Dakota may be influenced by hydrological conditions, with increasing wetness possibly resulting in increased statewide abundance. This is consistent with Plissner and Haig (2000) who suggested that "piping plover distribution and habitat use in the U.S. Great Plains/Canadian Prairie region may shift dramatically with water conditions." The data reported here suggest that regional population increases associated with increasing wetness may be due more to increased piping plovers per occupied site than they are to more sites being occupied.

The data do not imply however that drought years are not valuable to the long-term ecology of prairie wetlands, and indirectly, piping plover populations. Drought periods might retard vegetation growth along the shore of alkali wetlands (Root 1996). For some wetlands dry periods might result in larger expanses of barren beach that benefits piping plovers (Prindiville Gaines and Ryan 1988). As shown in my paper, some wetlands in North Dakota experienced increased piping plover populations with decreased wetness. Adding water to wetlands during dry periods needs to be weighed against these considerations, as well as the possibility that region-wide conditions might partially negate site-specific management, as was the case at Lake Williams. Adding water to Lake Williams might have maintained reproductive success at the site for the year (Weber and Martin 1991), but that may not always be the case. Increased water at a site, whether natural or anthropogenic, and increased piping plover abundance might not correlate with increased recruitment and survivorship (Van Horne 1983). Survivorship and recruitment are likely critical to the future recovery of the Great

Plains population of the piping plover (Larson et al. 2000).

Hydrological conditions strongly influence dam operations on the Missouri River mainstem, which in turn directly affect piping plover abundance. Similar to what is reported here, Mayer (1993) found a significant negative correlation between piping plover numbers and Garrison Dam water releases (i.e., Missouri River water levels) for 1982 to 1991. Further evidence of the impacts of dam releases is that the number of piping plovers on the Missouri River in 1995, a year with record low flows from 1968 to 1997, was 397.5% of what it was in the other years reported here. Conversely, in 1997, a year of record high flows from 1968 to 1997, only two piping plovers were recorded. Operating the Garrison Dam (and other Missouri River dams) consistent with pre-dam hydrographs commonly has been cited as a way to reverse the negative impacts the dams have had on Missouri River fish and wildlife populations (Hesse and Sheets 1993, Mayer 1993). High water levels during the breeding season not only directly displace piping plovers from the river, they also result in reduced habitat that makes the piping plovers and their nests more vulnerable to predators and human disturbance (Mayer 1993).

Understanding the relationship between Missouri River system populations of piping plovers and upland populations of piping plovers is confounded by lax survey synchronicity, unknowns about survey accuracy, varying water management within the mainstem, site-specific hydrological conditions in the uplands, and other factors. Nevertheless, the information presented here suggested that in dry periods both populations responded similarly. However, as water levels within the Missouri River system exceeded a certain point (i.e., water releases from Garrison Dam exceed 23,000 cfs and/or maximum daily elevations at Sakakawea and Oahe reservoirs exceeded 1836 and 1608 msl, respectively) the relationship between the Missouri River system population of piping plovers and the upland population of piping plovers becomes inverse, which suggests that Missouri River system piping plovers might move to upland sites within North Dakota during periods of high water on the mainstem.

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